Daily dry matter intake to sustain body weight of mature, nonlactating, nonpregnant cows[1]

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ABSTRACT: To quantify the relationship between DM consumption, the ability to sustain BW per unit of DMI (BW stasis), and days to reach BW equilibrium among diverse cattle breeds, weekly individual cow BW and DMI data were recorded for mature, nonpregnant, and nonlactating cows sampled from Angus, Braunvieh, Charolais, Hereford, Gelbvieh, Limousin, Pinzgauer, Red Poll, and Simmental breeds. Within each breed, cows were assigned to receive 1 of 4 daily DM allowances (56, 76, 93, or 111 g·BW$^{-0.75,\ kg}$) of a ground alfalfa hay-corn grain-based diet. Cows were housed in pens (space for 4 animals/pen) in open-front barns and fed individually using head gates. During the first 60 d of the experiment, BW were recorded every 28 d, after which BW were recorded on a weekly basis until the cows were determined to have attained BW equilibrium. Individual cows were determined to be at BW equilibrium when the rate of weekly BW change did not differ from 0 over an 8-wk period. The number of days to reach BW equilibrium was not affected ($P > 0.79$) by breed but was affected by the daily DM allowance ($P < 0.003$). The number of days required to attain BW equilibrium was greater as the rate of feeding (g of DM fed·BW$^{-0.75}$) increased and ranged from 103 to 136 d. Within breed linear and the pooled quadratic regressions were significant for BW. Observed breed differences varied with feeding rate. Weight stasis estimates for mature Red Poll cows (68.3 ± 3.8) differed ($P < 0.05$) from estimates for all the breeds, with the exception of Limousin (72.0 ± 3.8), Braunvieh (74.0 ± 4.8), and Pinzgauer (75.5 ± 3.8) cows at the lowest feeding rate. At the 111 g·BW$^{-0.75}$ daily DM allowance, the estimates for Limousin (82.2 ± 3.8) were greater ($P < 0.05$) than for the other breeds, with the exception of the Pinzgauer (81.0 ± 4.3) and Braunvieh (75.7 ± 3.9), which were similar to the remaining breeds in the study ($P > 0.05$). The change in rank of breed estimates for BW stasis suggests a breed × nutrition interaction for BW stasis.

Key words: beef cow, maintenance, weight stasis

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INTRODUCTION

Identification and quantification of factors affecting conversion of food resources to marketable product for cow-calf producers is an ongoing concern. Variation in genetic potential of output traits contributing to productivity has been investigated, with researchers providing evidence for variation among beef breeds for growth rates and mature size within and between breeds (Smith et al., 1976; Jenkins et al., 1991a; Meyer, 1995), and for daily milk yield at peak lactation within and between breeds (Beal et al., 1990; Jenkins and Ferrell, 1992; Minick et al., 2001). Differences among and within breeds for these output traits contribute to variation in conversion of food energy to marketable product, such as BW of the calf at weaning (Davis et al., 1983; Jenkins et al., 2000; Jenkins and Ferrell, 2004).

For calves weaned at 140 d, Jenkins et al. (2000) reported a quadratic relationship between calf BW at weaning and cow daily ME intake pooled over sire breed groups, with maximum weaning weight expressed at 29 Mcal/d. A positive linear relationship was reported between calf weaning weight at 200 d and cow daily DMI (Jenkins and Ferrell, 2004), but a negative linear relationship between grams of calf weaned/kilogram of DM consumed by the cow also was observed. An interaction between breed and annual BW of calf weaned and annual DM consumption by the cow was reported by Jenkins and Ferrell (1994), resulting in the same interaction for annual production efficiency (g of calf weaned/kg of annual DMI of the cow).

The objectives of the study were to 1) evaluate differences among diverse breeds of cattle for BW maintained

[1]Mention of a trade name, proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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per unit of DMI (BW stasis, kg/daily DMI, kg) and days required to attain BW equilibrium and 2) evaluate the effect of feeding rate on BW stasis and time required to attain BW equilibrium.

MATERIALS AND METHODS

Animals and Management

All animal procedures were reviewed and approved by the US Meat Animal Research Center Animal Care and Use Committee.

Mature, nonpregnant, nonlactating cows from Angus, Braunvieh, Charolais, Hereford, Gelbvieh, Limousin, Pinzgauer, Red Poll, and Simmental breeds were sampled from a life cycle efficiency project (Jenkins and Ferrell, 1994). At the initiation of the life cycle efficiency study, representative cows of each breed were assigned randomly to 1 of 4 rates of daily DMI (56, 76, 93, or 111 $g \cdot BW^{-0.75}$). Daily diet intakes were calculated using these rates and the initial BW of the cows at the time of assignment to the life cycle efficiency project. During the calf production component of the life cycle efficiency study, the daily DM allowance was increased by 25% during lactation (Jenkins and Ferrell, 1992). After weaning of the last calf, each cow's DM daily feed rate was reduced from the lactation phase level of daily DMI to the assigned daily intakes specified above. Each cow that contributed to the data set remained on this feeding level until BW equilibrium was attained. Cows were housed in open-front barns with concrete flooring. Pen size was approximately 11.7 × 6.1 m. Each pen was equipped with 4 electronic head gates (American Calan, Northwood, NH). Breed and feeding rate were confounded with pen.

A total of 130 cows representing Angus (15), Braunvieh (13), Charolais (14), Gelbvieh (16), Hereford (11), Limousin (16), Pinzgauer (14), Red Poll (16), and Simmental (15) from the life cycle efficiency project were available for the evaluation of BW maintained per kilogram of DMI (BW stasis); the number within parentheses represents the number of cows contributing to the study. Cows ranged in age from 6 to 10 yr. Beginning at approximately 90 d after weaning of the last calf (approximately January 1), cow BW were recorded at 28-d intervals for 56 d, after which individual cow BW were recorded weekly until each cow was considered to have reached BW equilibrium. Weights were recorded in the morning before feeding.

Diet composition is presented in Table 1. The diet was fed daily, with feed refusals by individual animals weighed on a weekly basis when required. Feed refusals were routinely observed at the greatest feeding rate but not at the 2 lowest feeding rates. Feed consumption was summed weekly for individual cows. Samples of feed were taken daily, and composites were prepared and sampled weekly for determination of DM.

Cows were considered to have achieved BW equilibrium when the regression coefficient from the regression of individual animal weekly BW on the dates of measurement did not differ from 0 for 8 consecutive weekly measurements. Cows attained BW equilibrium during the months of May through October. Means for BW at BW equilibrium, daily DMI, and days to reach 0 BW change are reported in Table 2. Daily DMI is defined as the feed consumed during the 8 wk before removal from the study (sum of total weekly ration − weekly refusals) divided by 56 d.

Table 1. Composition of the diet[1,2]

Item	Composition
Ingredient	
Ground alfalfa hay, %	77.50
Corn, rolled, %	17.50
Corn silage	5.00
Formulated nutrient composition	
ME, Mcal/kg	2.25
CP, %	16.00

[1]Dry matter basis; nutrient contents calculated from tabular values (NRC, 1984).

[2]Salt block provided free choice and beef trace mineral mix containing 14% Ca, 12% Zn, 8% Mn, 10% Fe, 1.5% Cu, 0.2% I, and 0.1% Co. (Consumer Service, North Sioux City, SD).

Data Analyses

Days to attain BW equilibrium and BW maintained per unit of DM were identified as the traits of interest. Taylor and Young (1968) suggested that measures of maintenance were needed for mature animals differing in mature BW. Using experimental designs resulting in BW equilibrium at constant feed intake provides an estimate of the efficiency of maintenance. Differences in maintenance efficiency at various feeding rates among breeds may be evaluated using this approach. As reviewed by Ball et al. (1998), regressing group means for estimated composition gains or BW gains on energy intake and extrapolating back to 0 may introduce confounding of between-animal variation in the maintenance estimate. The applied protocol of allowing individual animals to attain BW equilibrium to investigate the relationship between feed allowance and maintenance used in the current study circumvents this risk but makes the assumption that at BW equilibrium there is 0 change in body energy, which may not be valid. The protocol used in this study assumes that BW maintained per unit of feed consumed by nonpregnant or lactating cows reflects differences in maintenance of a producing animal (i.e., pregnant or lactating, or both), or results in a similar ranking among breeds.

Traits of interest were days to reach BW equilibrium and BW stasis (BW maintained per unit of daily DMI). Analyses of covariance (Steele and Torrie, 1960) were used to partition variation associated with the fixed effect of breed and the covariate of feeding rate (the 4 rates of daily DMI). Initial analyses included breed, pooled linear and quadratic terms for feeding rate, and the interaction of these terms with breed. Where appro-

Table 2. Means (SD) for traits of interest for 9 breeds fed at 4 feeding rates

		Feeding rate, g of daily DMI·kg of BW$^{-0.75}$			
Breed	Trait	56	76	93	111
Angus	Final BW, kg	514 (39)	588 (43)	611 (54)	610 (45)
	Daily DMI, kg	6.5 (0.5)	7.8 (0.5)	9.0 (0.6)	9.3 (1.5)
	Days to zero BW change	80 (15)	119 (17)	142 (65)	122 (54)
Braunvieh	Final BW, kg	514 (84)	578 (47)	729 (80)	706 (104)
	Daily DMI, kg	6.6 (0.5)	9.1 (0.4)	10.6 (1.2)	9.6 (1.7)
	Days to zero BW change	126 (49)	103 (62)	179 (83)	147 (53)
Charolais	Final BW, kg	579 (69)	702 (45)	770 (65)	750 (81)
	Daily DMI, kg	7.1 (0.8)	10.1 (0.5)	11.3 (0.4)	11.5 (0.6)
	Days to zero BW change	116 (56)	164 (31)	125 (42)	86 (6.7)
Hereford	Final BW, kg	593 (91)	564 (51)	723 (16)	687 (21)
	Daily DMI, kg	6.9 (0.4)	8.7 (0.2)	9.6 (0.1)	10.4 (0.9)
	Days to zero BW change	100 (14.5)	142 (65)	126 (49)	131 (57)
Gelbvieh	Final BW, kg	569 (57)	622 (92)	687 (85)	753 (75)
	Daily DMI, kg	6.7 (0.4)	8.8 (0.7)	11.1 (0.9)	10.3 (0.9)
	Days to zero BW change	89 (15)	143 (36)	170 (59)	154 (14)
Limousin	Final BW, kg	502 (84)	579 (32)	664 (40)	690 (92)
	Daily DMI, kg	6.7 (0.4)	9.4 (0.8)	8.7 (1.8)	8.7 (1.9)
	Days to zero BW change	103 (13)	110 (51)	138 (51)	161 (74)
Pinzgauer	Final BW, kg	500 (44)	592 (42)	681 (85)	737 (34)
	Daily DMI, kg	6.6 (0.6)	8.7 (0.59)	9.2 (0.4)	9.3 (1.4)
	Days to zero BW change	120 (55)	119 (42)	89 (42)	102 (18)
Red Poll	Final BW, kg	434 (51)	465 (35)	544 (59)	637 (80)
	Daily DMI, kg	6.5 (0.8)	7.3 (0.5)	9.0 (0.8)	9.5 (1.9)
	Final BW, kg	103 (48)	117 (58)	136 (28)	145 (64)
Simmental	Final BW, kg	560 (75)	612 (70)	806 (98)	740 (70)
	Daily DMI, kg	7.0 (0.5)	9.3 (0.6)	11.5 (1.6)	10.7 (0.6)
	Final BW, kg	107 (33)	112 (8)	107 (22.5)	154 (58)

priate, subclass linear or quadratic regressions, or both, remained in the final models to estimate least squares means for breed using PROC GLM (SAS Inst. Inc., Cary, NC). Sources of variation included in the initial model were breed, the pooled linear and quadratic covariates for rate of feeding per metabolic body size (BW$^{0.75}$) assigned when the cows began the life cycle efficiency evaluation, and these terms nested within breed for the initial analyses. Residual error mean squares for each response variable were used to test the sources of variation.

RESULTS AND DISCUSSION

Analysis of Covariance

Sums of squares associated with sources of variation and df are reported in Table 3 for days to reach BW equilibrium and BW stasis. Sources of variation for days required to reach BW equilibrium and BW stasis were tested against the residual error mean square.

The total amount of variation accounted for by breed in the model for days to attain BW equilibrium was not significant ($P > 0.79$) but the linear effect of feeding rate affected the number of days to attain BW equilibrium was highly significant ($P < 0.003$). The positive regression coefficient (0.56 ± 0.2) indicates that the number of days required to attain BW equilibrium increased as grams of DM fed BW$^{-0.75}$ increased. Taylor and Young (1968) indicated time needed to attain BW equilibrium for growing, nonpregnant, nonlactating females fed at rates exceeding that required for maintenance was dependent on feeding rate. Twin juvenile females in that study receiving the greatest daily rations required up to 7 yr to attain BW equilibrium, whereas those fed at the lowest level could exceed 5 yr. The pooled mean estimate for days to reach BW equilibrium of nonlactating and nonpregnant mature cows sampled from 9 breeds of beef cattle was 125 d with a SD of 46.4 d.

Breed Feeding Rate Response

Results of the analyses for breed BW stasis are reported in Table 3. The pooled quadratic regression was

Table 3. Sums of squares from analysis of covariance for days to attain BW equilibrium and BW maintained per daily DMI for mature cows fed at 4 daily DMI rates

Source of variation	df	Days to BW equilibrium	BW maintained/ daily DMI, kg/kg
Breed	8	9,532	1,476*
Feeding rate			
Linear	1	15,793**	
Quadratic	1		1,641**
Linear (breed)	9		1,862*
Residual	111 (121)	277,467	8,642
R^2		0.096	0.339

*$P < 0.05$; **$P < 0.01$.

Table 4. Least square means (SE) for BW stasis[1] for 9 breeds fed at 4 feeding rates

	Feeding rate, g of daily DMI·kg of BW$^{-0.75}$			
Breed	56	76	93	111
Angus	82.8 ± 3.8^{a}	71.1 ± 2.6^{a}	66.8 ± 2.6^{ab}	69.4 ± 3.9^{b}
Braunvieh	74.0 ± 4.8^{ab}	67.4 ± 3.0^{ab}	68.0 ± 2.6^{b}	75.7 ± 3.9^{ab}
Charolais	83.3 ± 4.1^{a}	78.3 ± 2.6^{a}	65.8 ± 2.7^{b}	67.6 ± 3.9^{b}
Hereford	82.5 ± 4.3^{a}	71.2 ± 2.9^{a}	67.2 ± 3.0^{b}	70.2 ± 4.5^{b}
Gelbvieh	82.5 ± 3.8^{a}	70.9 ± 2.5^{a}	66.7 ± 2.5^{b}	69.4 ± 3.8^{b}
Limousin	72.0 ± 3.8^{ab}	68.3 ± 2.6^{a}	71.6 ± 2.5^{ab}	82.2 ± 3.8^{a}
Pinzgauer	75.5 ± 3.8^{ab}	70.2 ± 2.6^{a}	72.0 ± 2.8^{ab}	81.0 ± 4.3^{a}
Red Poll	68.3 ± 3.8^{b}	61.3 ± 2.5^{b}	61.5 ± 2.6^{b}	68.8 ± 3.8^{b}
Simmental	79.4 ± 3.8^{a}	69.2 ± 2.6^{a}	66.3 ± 2.6^{ab}	70.4 ± 3.9^{b}

[a,b]Means within column with different superscripts differ ($P < 0.05$).
[1]Weight maintained, kg of BW/kg of daily DMI.

significant ($P < 0.01$) for BW stasis, and the subclass linear regression for feeding rate was a significant ($P < 0.02$) source of variation. Significant subclass regressions indicate breeds BW stasis estimates vary due to DM availability, indicating a breed × nutrition interaction.

The pooled quadratic response to feeding rate was positive (0.011 ± 0.002). Subclass linear regression coefficients differed from the pooled regression (–1.81 ± 0.42) for Angus (–0.36 ± 0.16; $P < 0.04$), Charolais (–0.40 ± 0.17; $P < 0.02$), Gelbvieh (–0.35 ± 0.16; $P < 0.04$), Hereford (–0.33 ± 0.18; $P < 0.06$), and Simmental (–0.27 ± 0.16; $P < 0.10$) but not for the other breeds ($P > 0.57$).

Least square means and SE for BW stasis (kg of BW/kg of daily DMI) by breed at each of the 4 feeding rates are reported in Table 4. At the lowest feeding rate, estimated BW stasis for mature Red Poll cows (68.3 ± 3.8) differed ($P < 0.05$) from all breeds except the Limousin (72.0 ± 3.8), Braunvieh (74.0 ± 4.8), and Pinzgauer (75.5 ± 3.8). At 76 g·BW$^{-0.75}$ feed rate, Red Poll (61.4 ± 2.5) supported less ($P < 0.05$) BW·kg^{-1} of daily DMI than all other breeds except Braunvieh (67.5 ± 3.0), which did not differ from the other breeds ($P > 0.05$). At the 93 g·BW$^{-0.75}$ feeding, the only breed differences in BW stasis observed were Pinzgauer (71.9 ± 2.8) and Limousin (71.6 ± 2.5) being greater ($P < 0.001$) than the Red Poll estimate (61.5 ± 2.5). At the feed presentation rate of 111 g·BW$^{-0.75}$ rate, the BW stasis estimate of the Limousin (82.2 ± 3.8) was greater ($P < 0.05$) than the rest of breeds with the exception of the Pinzgauer (81.0 ± 4.3) and Braunvieh (75.7 ± 3.9). The Braunvieh estimates were similar to the remaining breeds in the study ($P < 0.05$).

Ferrell and Jenkins (1985) reported estimates of ME required for maintenance of mature cows in varying physiological states using a retained energy approach. Using the BW information in Table 2 and the ME concentration of the diet (Table 1) of 2.25 Mcal, the ME required for maintenance at the lowest feeding level in the current study are similar to estimates of breeds crosses or breeds reported by Ferrell and Jenkins (1985; e.g., Simmental 134 vs. 138 kcal of BW$^{0.75}$ and Hereford 133 vs. 120 kcal of BW$^{0.75}$). Jenkins et al. (1991b) reported that daily heat production changed with increasing DMI; 47 g of DMI·BW$^{-0.75}$, 60 g of DMI·BW$^{-0.75}$, 72 g of DMI·BW$^{-0.75}$, and 85 g of DMI·BW$^{-0.75}$. Daily heat production was measured using open circuit calorimetry and increased with greater DMI for nonlactating, nonpregnant Simmental and Hereford cows. A linear relationship was observed between feeding rate and daily heat production with the regression coefficient differing between the breeds ($P < 0.05$). The predicted value for daily heat production for Hereford was lower than Simmental at the lowest feeding rate (47 g of BW$^{0.75}$), but the predicted heat production of the Hereford at the greatest level of daily DMI (85 g of BW$^{0.75}$) was greater than the predicted daily heat production of the Simmental.

Fluctuations in estimates of maintenance associated with increasing or decreasing feed allowances have been documented in growing pigs, sheep, and rats (Koong et al., 1983; Ferrell et al., 1986; Ferrell and Koong, 1986). In these studies indirect estimates of maintenance were obtained via refeeding trials, animals were assigned a daily feed allowance, received that ration for a predetermined time, and then were reassigned to a different daily feed allowance. At the beginning of the study, feed allowance change points and at the end of the experiment, animals of same BW from each of each of the previous feeding levels were killed. Evidence from these studies indicated previous nutrition levels affected current maintenance requirements and the effect could be mediated through changes in mass of body organs associated with high levels of metabolic activity (e.g., liver, heart, kidney, and gut). Consistent with these researchers, Freetly and Nienaber (1998) and Freetly et al. (2006) reported fasting heat production determined from individual cow oxygen consumption, carbon dioxide, and methane production for mature nonpregnant or -lactating cows restricted fed (35% reduction from initial intake levels) of a ration with low energy content. Daily heat production of cows receiving the restricted ration treatment decreased relative to control cows. With realimentation to 135% of initial intake level, fasting heat production of the restricted treatment animals exceeded that of the control animals.

Ball et al. (1998) reported results from mature sheep fed for 15 wk at maintenance or less then refed at 100% maintenance for 15 wk. Computer-assisted tomography was used to monitor mass changes in empty body components of individual rams and ewes to predict energy fluxes. Estimates of maintenance (calculated as difference between ME intake and RE for empty body tissues) for those animals losing BW declined during the earlier phase of the BW loss period then stabilized; then, following realimentation, the maintenance requirement increased similar to the pattern observed in the current study. These changes in maintenance requirements were associated with changes in mass of empty body components predicted from the serial computer-assisted tomography scan images.

The amount of energy required for maintenance of a beef cow constitutes a substantial proportion of the annual energy requirement of a cow (Gregory, 1972). Ferrell and Jenkins (1984) reported differences in energy required for maintenance among mature F1 cows differing in genetic potential for mature size and lactation. Greater maintenance energy requirements could negatively affect reproduction during times of low food or stored energy availability under management systems with restricted breeding seasons (Short et al., 1990) by increasing the postpartum interval (Nugent et al., 1993).

With 60 to 70% of annual energy cost associated with sustaining the cow, the potential for food availability × breed interaction for maintenance energy requirements during a production year may account for some of the differences in production efficiency reported by Jenkins and Ferrell (1994). Results from that study indicated with increasing energy allowance, those breeds characterized as having increased production potential for milk production, growth, or both were more effective in converting feed resources into the BW of the calf at weaning.

Presently, the beef industry evaluates feed efficiency during the postweaning period. Animals are fed to appetite high energy density diets for a defined period. Ranking individuals for feed efficiency may be appropriate to identify those individuals in this type of nutritional environment, but results from the current study indicate that the efficiency of maintenance varies with feed availability in mature cows.

The annual production cycle of beef cows is based on forage environment that can vary in the availability of DM and quality that can be readily consumed, which may affect the ability of cows to convert feed resources to calf weaning weight on a herd basis. Limitations in DM availability may result in reduced expression of genetic potential for production traits such as pregnancy rate or total milk yield, which contributes to the reduction of total calf sale weight. A dynamic mechanism for maintenance requirements may create an opportunity for cattle producers to utilize variation among breeds of beef cattle to better match the genetic potential for production to the forage environment. However, if feed allowance influences energy requirement for maintenance, basing improvement in cow feed efficiency upon selection criteria in the postweaning growing period with ad libitum feeding of high energy diets to replacement heifers may not be appropriate in all production environments.

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